Working Paper 94-1 / Document de travail 94-1

OPTIMUM CURRENCY AREAS AND SHOCK ASYMMETRY

A Comparison of Europe and the United States

by
Nick Chamie, Alain DeSerres
and René Lalonde

Bank of Canada Banque du Canada

January 1994

Optimum Currency Areas and Shock Asymmetry: A Comparison of Europe and the United States

by

Nick Chamie, Alain DeSerres and René Lalonde

International Department
Bank of Canada
Ottawa, Ontario, Canada
K1A 0G9

Tel.: (613) 782-7334
Fax.: (613) 782-7658

An earlier version of this paper was presented at the 1993 Canadian Economics Association meetings. Any correspondence concerning this paper should be addressed to Alain DeSerres.

Acknowledgments

We would like to thank Robert Amano, Robert Lafrance, Pierre St-Amant and especially Simon van Norden for useful comments and suggestions. We also thank David Miller for his contribution in the translation of the paper, Helen Meubus for editorial advice and Lisa Provost for secretarial assistance. The responsibility for errors is ours.

ISSN 1192-5434
ISBN 0-662-21397-1
Printed in Canada on recycled paper

Contents

Abstract

The authors examine the optimality of the European Monetary Union (EMU) by estimating the degree of asymmetry in shocks affecting thirteen European countries and comparing the results to those obtained for nine U.S. regions. First, they identify supply shocks and real and nominal demand shocks by imposing restrictions on the long-term effects of these on the level of output, prices and money. This decomposition is necessary to develop a measure of shock asymmetry that is not affected by country-specific monetary policy disturbances.

Next, the unobservable common and specific components of structural shocks are identified by means of state-space models. The results show that both supply and real demand shocks affecting the regions of the United States are much more symmetrical than those affecting the European countries.

In Europe, only Germany and Switzerland are strongly related to the symmetrical component of shocks. The fact that Greece, Italy, Norway, Portugal and Sweden are not statistically related to the common component of the shocks suggests that they may face significant adjustment costs by participating in the European Monetary Union. However, these countries appear to be characterized by a smaller degree of nominal rigidity, which could partly offset the impact of asymmetrical shock by facilitating the adjustment. Shocks affecting France, Belgium, the Netherlands, the United Kingdom and Spain are largely asymmetrical, though statistically related to the common components.

Résumé

Les auteurs examinent l'optimalité de l'Union Monétaire Européenne (UME) en partant d'une évaluation empirique du degré d'asymétrie des chocs d'offre et de demande auxquels sont soumis treize pays d'Europe et en comparant les résultats avec ceux qu'ils ont obtenus pour neuf régions des États-Unis. Dans un premier temps, ils identifient les chocs d'offre ainsi que les chocs de demande réels et nominaux à l'aide de restrictions imposées aux effets que ces chocs peuvent avoir à long terme sur le niveau de la production, des prix et des encaisses réelles. Cette opération est nécessaire pour obtenir une mesure des chocs asymétriques qui ne soit pas affectée par les effets de la politique monétaire spécifique de chaque pays.

Dans un deuxième temps, les auteurs déterminent les composantes inobservables communes et spécifiques des chocs structurels en utilisant des modèles d'espace-d'état. Les résultats montrent que les chocs d'offre et de demande réels affectant les régions américaines sont dans l'ensemble plus symétriques que ceux qu'enregistrent les pays européens.

En Europe, seuls les chocs affectant l'Allemagne et la Suisse sont fortement associés à la composante symétrique. Le fait que les chocs auxquels sont soumis la Grèce, l'Italie, la Norvège, le Portugal et la Suède ne soient pas reliés statistiquement à la composante commune indique que ces pays pourraient faire face à d'importants coûts d'ajustement en adhérant à l'UME. Toutefois, ils semblent caractérisés par un degré de rigidités nominales plus faible, ce qui pourrait faciliter leur ajustement à un choc asymétrique. Les chocs touchant la France, la Belgique, les Pays-Bas, le Royaume-Uni et l'Espagne sont largement asymétriques, quoique statistiquement rattachés à la composante commune.

1 Introduction

Under the Maastricht treaty, the countries of the European Union (EU) will enter into a monetary union by the late 1990s. Discussions surrounding the European monetary union (EMU) and the recent steps towards greater economic integration (for example, the Europe 1993 agreements) have given a new impetus to the study of optimum currency areas. In a series of seminal papers, Mundell (1961), McKinnon (1963) and Kenen (1969) identified a series of criteria for defining such areas.[1] One of the important criteria mentioned in the literature is the degree of asymmetry of macroeconomic shocks. Because monetary union implies that the nominal exchange rate can no longer move to facilitate the adjustment to specific shocks, the costs associated with the loss of monetary policy independence increase with the degree of shock asymmetry between countries.[2]

Our main objective in this paper is to contribute to the debate on optimality of a European currency area by analysing the degree of shock asymmetry. It should be noted that there is no absolute yardstick for deciding whether a given currency area is optimal or not. To gauge the optimality of the EMU, therefore, a basis for comparison is needed. In this study, the results for the European countries are compared with those for a long-established monetary union, the United States, disaggregated into nine regions.[3]

To evaluate the desirability of a monetary union, an appropriate measure of shock asymmetry should exclude the effects on economic activity of independent monetary policy movements, since the asymmetry induced by country-specific monetary policy shocks would be eliminated under such an arrangement. One way to purge these effects is to decompose aggregate shocks into their unobserved supply and demand components and focus exclusively on the symmetry of the former, on the assumption that supply innovations are not affected by monetary policy. However, this method leads to the exclusion of an important category of shocks not related to monetary policy, that of real demand shocks (for example, fiscal or consumer preference shocks). In order to obtain a measure that excludes only the effect of nominal innovations, we propose a decomposition of demand shocks into real and nominal sources. This is done by estimating a quarterly vector autoregression (VAR) composed of the index of industrial production, the consumer price index and the M1 monetary aggregate. In accordance with the approach developed by Blanchard and Quah (1989), the structural shocks of each country are identified by means of restrictions placed on their long-term effects.

1. For a recent survey of the literature, see Fenton and Murray (1992), Masson and Taylor (1992) and, concerning European monetary unification, Eichengreen (1993).

2. These costs are associated in particular with increased variability in output and unemployment.

3. This is a common approach in studies in this area; see, in particular, Bayoumi and Eichengreen (1992).

To assess the degree of shock symmetry, Bayoumi and Eichengreen (1992) measure the correlation of supply shocks of various regions with those of an anchor region. This approach has some drawbacks. First, the results may be sensitive to the choice of an anchor region. In addition, the method does not explicitly distinguish between the structural symmetrical and asymmetrical components of shocks. In this paper, we adopt a different methodology. It consists of estimating state-space models to decompose previously identified shocks into unobservable symmetrical and asymmetrical components. This method has the advantage of not being influenced by the choice of an anchor region. In addition, it decomposes supply and demand shocks into their structural common and specific components, making it easier to interpret the results than if an analysis based on correlations were used.[4] While specific shocks are asymmetrical by definition, shocks related to the common component will be symmetrical (asymmetrical) if the associated coefficient has a positive (negative) sign.

While the degree of shock asymmetry is an important criterion for the choice of an optimum currency area, it only matters to the extent that various forms of rigidities prevent prices and wages from adjusting rapidly to their new equilibrium values. In other words, the more efficiently alternative adjustment mechanisms operate, the smaller will be the costs associated with asymmetrical shocks in a monetary union. Therefore, we also examine the speed of adjustment of output and prices to supply and real demand shocks.

In their study on EMU, Bayoumi and Eichengreen (1992) conclude that both demand and supply shocks are generally much more symmetrical in the United States than in Europe, suggesting that a majority of European countries may face significant costs by joining a monetary union. DeSerres and Lalonde (1993) reach a similar conclusion from their study of the magnitude of real shocks affecting real exchange rates in Europe. The results of the present study would tend to support the view that relative to the United States, the degree of real shock asymmetry is significantly larger in Europe. Although this broad conclusion is consistent with the findings of Bayoumi and Eichengreen, our results differ from theirs in many respects. First, the set of countries or regions characterized by a large degree of shock asymmetry is different in our study. Second, in contrast to what Bayoumi and Eichengreen report in their paper, we find that the adjustment of output in response to a structural shock is slower in the U.S. regions than in the European countries.

In summary, we find that among the European countries, only Germany and Switzerland are strongly related to the common components of supply and real demand shocks. In fact, Germany is the main determinant of the common component of shocks in Europe. The transition period leading up to the monetary union may also prove more costly for Greece, Italy, Norway,

4. This method is used also by Lalonde and St-Amant (1993) in a study of the optimal currency choice for Mexico.

Portugal and Sweden, although these countries appear to have smaller nominal rigidities, a factor that will help reduce the adjustment costs associated with the prevalence of idiosyncratic shocks. The shocks affecting Belgium, France, the Netherlands, Spain, and the United Kingdom are largely idiosyncratic, even though they are statistically related to the common components.

The rest of the paper consists of five sections. The next section discusses the implications of shock asymmetry in the context of a common currency area. Section 3 describes the methodology. In the first part of the section the extension of the Blanchard and Quah method to a trivariate system is exposed and in the second part the state-space model is introduced. Section 4 discusses issues related to the data base. The results of the study are presented and analysed in Section 5. Finally, section 6 offers some conclusions.

2 Optimal currency areas and the role of shock asymmetry

Ever since the main costs and benefits of a common currency area were identified by the pioneering work of Mundell (1961), McKinnon (1963) and Kenen (1969), the focus of the literature has been to try to quantify some aspects of these costs and benefits. According to Fenton and Murray (1993), the benefits of a common currency area can be divided into four broad categories: reduced transaction costs, reduced economic uncertainty, enhanced policy discipline and credibility, and improved functioning of the monetary mechanism. While the set of benefits covers a mixture of micro and macro aspects, the costs that are usually identified fall essentially in the field of macro policy and can be divided into two related categories: reduced policy independence and greater economic instability.

In this paper, we focus exclusively on quantifying the cost of reduced policy independence and thus of greater economic instability. The cost of abandoning an independent monetary policy comes from the loss of an instrument that can be used to facilitate the adjustment of the economy following a shock that requires some changes in the real exchange rates to bring goods and labour markets back to equilibrium. As emphasized in a recent survey by Eichengreen (1993), this cost will be significant only if two conditions are met. First, the real shocks must be sufficiently asymmetrical for real exchange rate adjustment to be important.[5]

Second, monetary policy must be able to effectively stabilize the economy, and therefore to affect output. The latter condition requires that some form of nominal rigidities prevent prices and wages from adjusting rapidly to clear the markets. In this study, we cover both aspects of the question. We try to quantify the degree of shock asymmetry as well as the degree of nominal

5. We assume that factor mobility is sufficiently limited for asymmetrical shocks to generate significant and persistent movement in real exchange rates. For an empirical evaluation of the sources of fluctuations in real bilateral and real effective exchange rates in Europe, see DeSerres and Lalonde (1993).

rigidity for the European countries and the United States.

There have been several attempts to quantify the degree of shock asymmetry between the European countries in recent years. Cohen and Wyplosz (1989) estimated the degree of symmetry of real output fluctuations in France and Germany by comparing the variance of the detrended sum of real output in the two countries to that of the detrended difference between the same series, using alternative detrending methods. Following their interpretation, a large variance of the sum relative to the variance of the difference would indicate that the movement in real output in the two countries is largely symmetrical. They also applied the method to real wages and the price level and found that fluctuations in all three variables were largely symmetrical between France and Germany. Weber (1990) applied a similar methodology to other countries in the EU and also concluded in favour of predominantly symmetrical movements. The main drawback of this method is that by looking at the variance of an aggregate series such as real output, one cannot distinguish between the effects of shocks (impulse) and the dynamic response to these shocks (propagation).

This has led Bayoumi and Eichengreen (1992) to use a technique developed by Blanchard and Quah (1989) to decompose reduced-form residuals from a VAR of output and prices into structural demand and supply innovations. After applying the decomposition method to a set of European countries, they use simple correlation techniques to measure the degree of asymmetry of supply shocks between the countries included in their study. Although their approach represents a significant improvement compared to the Cohen and Wyplosz approach, it still suffers in our view from two important limitations, as we point out below.

3 Methodology

This section is divided into two parts. The first describes how supply shocks as well as nominal and real demand shocks are identified for each of the countries (or regions). The second part presents the state-space models used to identify the common and specific components of these shocks.

3.1 Identification of structural shocks

Bayoumi and Eichengreen estimate a bivariate VAR model of real output and prices for each of the EU countries and use long-run restrictions along the lines of Blanchard and Quah to identify aggregate supply and demand shocks. Then they examine cross-country (or cross-region) correlations for each of the two types of structural innovations. Unfortunately, because of the long-run identification restriction, any shock that has a temporary effect on real output is interpreted as a demand shock and presumably that includes monetary shocks. Therefore, in order to derive a measure of shock asymmetry that is purged from monetary policy effects, one could focus exclusively on the supply shock component in the analysis of the degree of asymmetry. However, certain real shocks (for example, fiscal or consumer preference shocks) that presumably have a negligible impact on potential output in the long run may have an important impact on the evaluation of the costs of losing exchange rate flexibility. We feel that it is important to analyse the degree of asymmetry of these shocks separately, since their impact will be different from that of permanent shocks and, contrary to monetary shocks, their frequency will not necessarily diminish under EMU.

In order to identify all relevant sources of output fluctuation, the decomposition method suggested by Blanchard and Quah is applied to a three-variable VAR system. For each country, it is assumed that the rate of growth of industrial production (Δy), consumer prices (Δp) and the M1 monetary aggregate, (Δm), follow a stationary stochastic process that responds to three types of orthogonal shocks: supply shocks (ε_s), real demand shocks (ε_d), and nominal shocks (ε_m).

This structural model can be expressed as a moving average as follows:

$$\Delta x_t = A_0 \varepsilon_t + A_1 \varepsilon_{t-1} + \ldots = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \tag{1}$$

where

$$\Delta x_t = \begin{bmatrix} \Delta y_t \\ \Delta p_t \\ \Delta m_t \end{bmatrix}$$

and

$$\varepsilon_t = \begin{bmatrix} \varepsilon s_t \\ \varepsilon d_t \\ \varepsilon m_t \end{bmatrix}$$

For simplicity, the variances of the structural shocks are normalized so that

$$E(\varepsilon_t \varepsilon_t) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{2}$$

and

$$E(\varepsilon_t \varepsilon_{t+i}) = 0, Vi \neq 0 \tag{3}$$

To identify this structural model, the vector autoregressive reduced form of the model is first estimated:

$$\Delta x_t = \Pi_1 \Delta x_{t-1} + \ldots + \Pi_q \Delta x_{t-q} + e_t \tag{4}$$

where

$$E(e_t e_t) = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix} = \Sigma \tag{5}$$

Given that the stochastic process is stationary, the model may be written in its moving-average form:[6]

$$\Delta x_t = e_t + C_1 e_{t-1} + \ldots = \sum_{i=0}^{\infty} C_i e_{t-i} = C(L) e_t \tag{6}$$

where $C(L)$ is an infinite-order lag polynomial such that $C_k L^k e_t = C_k e_{t-k}$. The residuals of the model's reduced form are thus related to the structural residuals as described in the following relation:

$$e_t = A_0 \varepsilon_t \tag{7}$$

such that

$$E(e_t e_t) = A_0 E(\varepsilon_t \varepsilon_t) A_0' \tag{8}$$

and

$$\Sigma = A_0 A_0' \tag{9}$$

The problem remains of identifying the structural shocks ε from the VAR reduced-form residuals e and their variance. From (7), we know that the solution depends on the identification of the matrix A_0, which contains n^2 elements (where *n* is equal to the number of dependent variables in the model). Since Σ is a symmetrical matrix, equation (9) gives $[(n^2 - n)/2] + n$ restrictions on the matrix A_0, Thus, $(n^2/2) - (n/2)$ extra restrictions must be imposed for complete identification, which means 3 extra restrictions in the context of our model.

The conventional way to identify the structural parameters of a VAR has been to identify the matrix A_0 as the Choleski decomposition of Σ. Cooley and Leroy (1985) criticized this

6. If certain variables were cointegrated, additional restrictions would be required. The results of stationarity and cointegration tests are presented in Appendix 2.

method on the grounds that the recursive causal structure implied is often hard to reconcile with any economic theory. Moreover, the interpretation of the results are often sensitive to the choice of a particular causal ordering.

In contrast, the approach used by Blanchard and Quah (1989) involves imposing restrictions on the matrix of long-term effects of structural shocks. Since these restrictions are usually well anchored in economic theory, they provide a less arbitrary way to orthogonalize the reduced-form errors. At a minimum, the results can be given a structural interpretation that is consistent with a well-accepted theoretical framework. Combining equations (1), (6) and (7), we obtain the following relationship between the matrix of long-term effects of structural shocks $A(1)$ and the equivalent matrix of reduced-form shocks $C(1)$:[7]

$$A(1) = C(1)A_0 \tag{10}$$

where the matrix C(1) is obtained from the reduced-form estimates and therefore contains known elements. The three necessary restrictions for complete model identification can now be imposed on the matrix of long-term effects of supply, real demand and nominal shocks on the dependant variables.[8] Two of these restrictions are that neither real nor nominal demand shocks have any permanent effect on output. On the grounds that in the long run output depends entirely on supply factors such as productivity and demographics, similar assumptions have been used by Blanchard and Quah and Bayoumi and Eichengreen. A third restriction is introduced to distinguish between nominal and real demand shocks. It is assumed that nominal shocks have the same permanent effect on the level of money and prices, so that real balances are money-neutral in the long run. Appendix 1 details the solution method of the system of equations based on these restrictions.

No restriction is imposed on the long-term effect of supply innovations on prices and money. Assuming no change in the money level, a positive supply shock is expected to produce a permanent decrease in the price level, since the supply curve will shift along the demand curve. Accordingly, we expect supply innovations to lead to a permanent increase in real balances. It is important to note also that no restriction is imposed on the model in the short run. Thus, given the possible existence of nominal rigidities, we expect demand shocks (both real and nominal) to have in most cases a non-negligible temporary effect on output. Intuitively, we also expect nominal shocks to affect output more slowly than real demand shocks, given the usual delay in the propagation of nominal shocks to aggregate demand. Finally, we expect the

---

7. $A(1)$ represents the value of the polynomial $A(L)$ for $L = 1$. Mathematically, this is the sum of all lagged coefficients included in $A(L)$.

8. In a recent article, Lippi and Reichlin (1993) claimed that the Blanchard and Quah decomposition can yield a non-fundamental solution. However, in a reply, Blanchard and Quah (1993) have argued that the conditions under which such a problem might occur were unlikely to be met in the context of standard applications of their method.

response of prices and output to be positively correlated to nominal and real demand shocks (in the short run) and negatively correlated to supply shocks.

3.2 Identification of common and specific components of structural shocks

One of the main objectives of the exercise is to assess the degree of asymmetry of shocks affecting the countries under study.[9] After identifying structural shocks in each country or region, Bayoumi and Eichengreen measure the degree of asymmetry by observing the contemporaneous correlation of the shocks in each of these regions against an anchor region. This aspect of their methodology also has certain drawbacks. First, the results may be influenced by the choice of anchor area. Second, their approach does not produce a decomposition of demand and supply shocks into their structural common and specific components, which makes it difficult to interpret the results concerning the correlation of shocks. The method presented in this section corrects these deficiencies.

In order to assess the degree of symmetry of supply, real demand and nominal shocks, a state-space model is estimated for each type of shock.[10] The purpose of the state-space model is to decompose the structural shocks (observable dependent variables) in each of the regions into two unobservable stochastic components: one common and the other specific.

The methodology is easily described with an example. Consider a model that decomposes the demand shocks affecting two regions (A and B) into unobservable common and specific components. The *measurement equation* of the state-space model links the dependent variables of the model to the unobservable variables α_t.

$$\begin{bmatrix} ed_t^A \\ ed_t^B \end{bmatrix} = \begin{bmatrix} z_{11} & 1 & 0 \\ z_{21} & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha_{1t} \\ \alpha_{2t} \\ \alpha_{3t} \end{bmatrix} \tag{11}$$

where the observable dependent variables of the model (ed_t^A, ed_t^B) are previously obtained from the Blanchard-Quah decompositions on output, prices and money supply for each of the coun-

9. In describing the methodology, we use alternatively the terms “common” (as opposed to “specific”) and “symmetrical” (as opposed to “asymmetrical”) components. In fact, the two terms are not strictly equivalent. As will become clearer, while the specific component is asymmetrical by definition, the common component may be either symmetrical or asymmetrical depending on the sign of the coefficient associated with it.

10. Since supply shocks, real demand shocks and nominal shocks are not correlated, they are dealt with separately. For a detailed explanation of state-space models, see Harvey (1981).

tries. The *transition equation* specifies the dynamic behaviour of the unobservable variables.

$$\begin{bmatrix} \alpha_{1t} \\ \alpha_{2t} \\ \alpha_{3t} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} n_{dt} \\ n_{dt}^{A} \\ n_{dt}^{B} \end{bmatrix} \tag{12}$$

where

$$E(nn') = \begin{bmatrix} 1 & 0 & 0 \\ 0 & Q_{22} & 0 \\ 0 & 0 & Q_{33} \end{bmatrix}$$

In this particular application, the unobservable components are described as having no serial correlation, since by virtue of the Blanchard-Quah method, the structural residuals are not autocorrelated.[11]

The model decomposes demand shocks of country A (ed_t^A) and country B (ed_t^B) into an unobservable common component (α_{1t}), a component specific to country A (α_{2t}) and a component specific to country B (α_{3t}), identifying thereby a common demand shock (n_{dt}), as well as one specific to country A (n_{dt}^A), and one specific to country B (n_{dt}^B).[12] The coefficients z_{11} and z_{21} provide a measure of how strongly shocks facing country A and B are related to the common component. The sign of these coefficients will determine whether these common shocks are symmetrical or asymmetrical. To be precise, a negative (positive) coefficient implies that common shocks are asymmetrical (symmetrical). As for specific shocks, they are asymmetrical by nature.

For purposes of identification, the common and specific shocks are assumed to be uncorrelated. In order to standardize the scale of the unobservable variables, the variance of common shocks is set to unity. The unobservable shocks are generated by a Kalman filter.[13] To assess the relative magnitude of the common and specific components of supply, real demand and nominal shocks, a decomposition of the variance of structural innovations is carried out for each country. The decomposition is calculated from the estimated variance of shocks affecting each country. For example, equation (13) presents the variance of demand shocks affecting country A as spec-

---

11. In general applications, more complex dynamics can, of course, be defined.

12. Note that this method allows several types of common components to be identified simultaneously.

13. See Harvey (1981) for a description of the Kalman filter. Estimates are obtained from a maximum likelihood technique using EM and scoring algorithms, as suggested by Engle and Watson (1983). This was facilitated by the use of an algorithm programmed by Raynauld, Sigouin and Simonato (1992). With this algorithm, the initial values of unobservables and their variances are set according to the mean and the unconditional variance.

ified in equations (11) and (12):

$$VAR\,(e_d^A) \;=\; z_{11}^2 + Q_{22} \tag{13}$$

Given that specific and common shocks are uncorrelated, the proportion of variance of the shocks that is explained by the common component may be expressed as follows:

$$z_{11}^2 / (z_{11}^2 + Q_{22}) \tag{14}$$

This completes the description of the methodology. Before proceeding to the results, the following section describes the data base used.

4 Data sources, stationarity and cointegration tests

Quarterly data on the money supply (M1), the index of industrial production and the consumer price index[14] are used for the United States (aggregated and decomposed into nine regions) and for a group of thirteen European countries.[15] The data are logarithmic and the sample covers the period from the first quarter of 1970 to the final quarter of 1991. In most cases, the data are derived from national sources. A detailed list is available on request.[16]

Some of the identifying restrictions imply certain assumptions about the process characterizing the time series. The results of testing some of these hypotheses are presented in summary form in Appendix 2.[17] With the exception of one test for Sweden, the results are not inconsistent with the restrictions imposed on the structural shocks. In addition, excepting France, the results suggest that the VARs should be modelled in first-difference form without a deterministic trend and without cointegration terms. A deterministic trend is included in the VAR specification for France only. Otherwise, the VAR specification is the same.

---

14. Even though data on the real gross domestic product (GDP) and its deflator would have been more appropriate measures of output and prices, they are not available on a quarterly basis for the U.S. regions. Therefore, in order to have comparable results, we preferred to use CPIs and indexes of industrial production for both the U.S. regions and the European countries.

15. The thirteen European countries are Austria, Belgium, France, Germany, Greece, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. These countries were selected partly on the basis of their membership in the European Union or the European Free Trade Association and partly on the basis of data availability which explains why some are excluded.

16. Some data are derived from an OECD publication (*Main Economic Indicators*): CPI for Norway and Switzerland, M1 for Sweden and Switzerland, and industrial production for Belgium, Italy, Norway and Sweden. CPI and production data for the United Kingdom are from the Central Statistics Office (*CSO Economic Trends*). For France, M3 data were used instead of M1, since the latter were incomplete. Lastly, regional data for the United States come from Data Resources Inc.

17. For U.S. regions, see Lalonde and St-Amant (1993).

5 Results

The description of the results is divided into four parts.[18] In order to gauge the relative magnitude of the three identified structural shocks, the first part presents the decomposition of output variance for the European countries and U.S. regions. The second part focusses on the degree of asymmetry of the respective structural shocks between the thirteen European countries and the nine U.S. regions. This provides an empirical assessment of the state of economic integration in Europe in comparison to the United States and it also helps to identify the countries that are more likely to face significant adjustment costs under EMU. The third part assesses the degree of nominal rigidities in each country by measuring the slope of the short-run supply curve and by analysing the impulse response of output and prices to structural innovations. This is important, since under complete price flexibility, the degree of real shock asymmetry would not be a significant factor in the evaluation of the costs of losing monetary policy independence. The analysis of impulse response functions serves two purposes. First, it provides an opportunity to verify whether the short-run impact of the identified shock is intuitively appealing. Second, it allows for a comparison of the speed of adjustment of output and prices across the different countries.

5.1 Variance decomposition of output

The relative contributions of supply, real demand and nominal shocks to output fluctuations in each U.S. region and European country are presented and briefly discussed in the next two subsections.

5.1.1 U.S. regions

Table 1 shows, over different time horizons, the proportion of output variance attributable to supply, real demand and nominal shocks, respectively. Given the restrictions used, the variance of output in the long run is by definition entirely attributable to supply innovations. In the short and medium terms, supply shocks are relatively larger in New England and the Central Southwest. In the latter case, the relative importance of the petroleum sector could be a major factor. For the other regions, supply shocks, become a more significant source of fluctuation than nominal and real demand shocks once the horizon exceeds two years. For example, at impact, nominal and real demand shocks to these regions explain over 94 per cent of output variance. For all regions as a whole, the importance of real demand shocks is largest at impact. On the other hand, the peak effect of a nominal shock is usually felt after a lag of four to eight quarters.

---

18. With the exception of France (see Section 4), the results are presented without a linear trend in the first-difference VARs. For the other countries, the main results and principal conclusions are not affected by the inclusion of a linear trend.

Table 1: Variance decomposition of industrial production - U.S. regions

Regions	Relative contribution of supply shocks (%)							
	Time horizon (quarters)							
	1	2	4	8	12	24	48	Long term
New England	36	44	58	77	86	94	98	100
Central Atlantic	6	12	22	45	64	86	94	100
Central Northeast	1	5	8	33	57	84	94	100
Central Northwest	5	10	15	32	52	81	93	100
South Atlantic	1	7	19	37	55	82	93	100
Central Southeast	4	8	18	38	58	84	94	100
Central Southwest	46	53	61	69	75	86	93	100
Pacific Northwest	0	4	10	35	57	83	93	100
Pacific Southwest	1	7	14	33	52	80	92	100

Regions	Relative contribution of real demand shocks (%)							
	Time horizon (quarters)							
	1	2	4	8	12	24	48	Long term
New England	64	56	41	20	12	5	2	0
Central Atlantic	86	77	60	34	21	8	3	0
Central Northeast	89	79	68	47	30	11	4	0
Central Northwest	88	83	76	56	39	15	6	0
South Atlantic	96	86	70	47	32	13	5	0
Central Southeast	89	78	65	43	28	10	4	0
Central Southwest	52	44	35	27	22	12	6	0
Pacific Northwest	70	67	59	43	30	12	5	0
Pacific Southwest	99	93	83	57	38	16	6	0

Table 1 *(continued)*

Regions	Relative contribution of nominal shocks (%)							
	Time horizon (quarters)							
	1	2	4	8	12	24	48	Long term
New England	0	0	1	3	2	1	0	0
Central Atlantic	8	12	18	20	15	6	2	0
Central Northeast	10	16	24	20	13	5	2	0
Central Northwest	7	7	9	12	9	4	2	0
South Atlantic	4	7	11	16	13	6	2	0
Central Southeast	7	14	17	19	14	6	2	0
Central Southwest	2	3	4	4	3	2	1	0
Pacific Northwest	30	29	31	21	14	5	2	0
Pacific Southwest	0	0	3	9	9	4	2	0

5.1.2 European countries

The first panel in Table 2 shows the proportion of output variance in the 13 European countries that is explained by supply shocks. At impact, supply shocks account for over 50 per cent of output variance in the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom. The results for the Netherlands, Norway and the United Kingdom may partially reflect the relative importance of their petroleum sectors. In Austria, Belgium, France, Germany, Italy, Switzerland on the other hand, a horizon of four to eight quarters is required before supply shocks account for more than half of output variance. Overall, supply innovations are a more significant source of short-run output fluctuation in Europe than within the United States.

As shown in the second panel in Table 2, in the short term, real demand shocks account for a significant source of output variations in France, Germany and Italy, but only a relatively marginal source of output fluctuation in Norway, Portugal and Spain. Finally, it can be seen from the third panel in Table 2 that nominal shocks in the latter three countries and in Austria explain a larger share of output variance than do real demand shocks.

To summarize, we find that supply shocks generally account for a larger proportion of short-term output variance in Europe than in the United States. This is particularly true for the

Table 2: Variance decomposition of industrial production - European countries

Countries	Relative contribution of supply shocks (%)							
	Time horizon (quarters)							
	1	**2**	**4**	**8**	**12**	**24**	**48**	**L.T.**
Germany	22	27	31	54	69	85	93	100
France	24	30	47	75	83	91	96	100
United Kingdom	57	61	71	83	89	95	98	100
Italy	29	33	51	71	77	87	93	100
Spain	72	74	82	89	93	96	98	100
Netherlands	72	65	71	79	85	92	96	100
Belgium	28	25	38	63	75	89	96	100
Switzerland	16	21	27	54	71	86	93	100
Austria	34	38	44	57	66	83	92	100
Sweden	61	69	83	92	95	97	99	100
Norway	85	85	84	90	93	97	98	100
Portugal	84	74	75	84	88	94	97	100
Greece	49	54	67	84	90	95	98	100

Countries	Relative contribution of real demand shocks (%)							
	Time horizon (quarters)							
	1	**2**	**4**	**8**	**12**	**24**	**48**	**L.T.**
Germany	73	67	62	39	22	10	4	0
France	72	69	52	23	16	8	4	0
United Kingdom	23	20	12	6	4	2	1	0
Italy	71	65	46	27	21	12	6	0
Spain	5	6	4	2	2	1	0	0
Netherlands	15	20	18	13	9	5	2	0
Belgium	46	45	35	20	14	6	2	0
Switzerland	46	51	52	32	20	10	5	0
Austria	21	27	27	16	12	6	3	0
Sweden	21	17	8	3	2	1	1	0
Norway	0	3	7	4	3	1	1	0
Portugal	2	5	5	4	3	2	1	0
Greece	26	19	14	7	4	2	1	0

Table 2 *(continued)*

Countries	Relative contribution of nominal shocks (%)							
	Time horizon (quarters)							
	1	2	4	8	12	24	48	L.T
Germany	5	6	7	7	9	6	3	0
France	4	2	1	2	1	1	0	0
United Kingdom	20	20	18	11	8	3	2	0
Italy	0	2	3	3	2	2	1	0
Spain	24	20	14	9	6	3	1	0
Netherlands	13	14	12	8	6	3	1	0
Belgium	27	30	27	17	12	5	2	0
Switzerland	37	28	21	14	9	4	2	0
Austria	45	34	29	27	22	12	6	0
Sweden	19	14	9	5	3	2	1	0
Norway	15	12	10	6	4	2	1	0
Portugal	14	21	20	12	8	4	2	0
Greece	25	27	19	9	6	3	1	0

Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom. Moreover, only in the case of France, Germany and Italy is the contribution of real demand shocks in the short run comparable to that found in most U.S. regions.

5.2 Degree of shock symmetry

In this section, we compare the degree of symmetry of supply and real demand shocks observed among the European countries with that found in the United States.

5.2.1 U.S. regions

Table 3 shows the results of the state-space models used to decompose into specific and common components shocks affecting the nine U.S. regions. The key fact to emphasize is that only supply shocks affecting New England are not statistically related to the common American component (at the 5 per cent significance level). In the other U.S. regions, the variance of supply

Table 3: Variance decomposition of structural shocks - U.S. regions

Relative contribution of common component (%)			
Regions	**Real demand shocks**	**Supply shocks**	**Nominal shocks**
New England	56	0*	71
Central Atlantic	86	59	97
Northeast Central	83	76	93
Northwest Central	85	71	94
South Atlantic	85	89	99
Central Southeast	95	89	96
Central Southwest	50	64	95
Pacific Northwest	66	62	80
Pacific Southwest	76	67	92

* Shocks that are not statistically related to the common component (5% significance level).

shocks explained by the common component varies from 59 to 89 per cent.

Generally speaking, real demand shocks exhibit even greater symmetry than supply shocks. This is particularly true in New England, where more than half of the variance of demand shocks is attributable to the common component, compared with none for supply shocks. This is consistent with the fact that states and local authorities do not have a large degree of autonomy in the conduct of fiscal policy. Nominal shocks affecting the U.S. regions are the most strongly related to the common component. Again, this is not surprising, given that these regions are subject to the same monetary policy and that, in contrast to measures of price and output, the same monetary aggregate is used across all U.S. regions.

The main advantage of the state-space methodology becomes more obvious when our results are contrasted to those of Bayoumi and Eichengreen, who examine correlations of shocks against an anchor region. In particular, by choosing the Mid-East region as the anchor (which corresponds to Central Atlantic in Table 3), they find quite naturally that neighboring regions (including New England) tend to have a large symmetrical component.

5.2.2 European countries

The results of two series of state-space models for Europe are presented in Tables 4 and 5. Table 4 shows the results for the thirteen European countries. Moreover, in order to focus on a group of European countries that reflect the geographical core of Europe and at the same time that are generally perceived to have better developed and more diversified industrial structures, Table 5 shows the results when Greece, Norway, Portugal, Spain and Sweden are excluded.[19]

The supply shock results indicate that, among the thirteen European countries, only the innovations affecting Germany and Switzerland are strongly related to the common European component.[20] Apart from these two countries, the highest degree of shock symmetry is found (surprisingly) in Spain and the United Kingdom. In any event, the degree of supply shock symmetry is generally much lower in Europe than in the United States.

As for real demand shocks, the highest degree of symmetry is again found for Germany and Switzerland. Aside from these two countries, the most symmetrical response to demand shocks is shown by Belgium, France, the Netherlands and Portugal. However, for Portugal, this result is not very meaningful, since real demand shocks explain only 5 per cent or less of output variance (Table 4). Again, as was the case for supply shocks, the real demand disturbances affecting Greece, Italy, Norway and Sweden are not statistically related to the symmetrical component of shocks. In the case of real demand shocks, this finding also applies to Spain. Finally, real demand shock symmetry is also much weaker among the European countries than in the United States. In fact, among European countries, only for Germany is the proportion of the common component anywhere near that found for the U.S. regions.

Table 5 shows that, when non-core European countries are excluded, Germany becomes even more closely related to the common component of shocks. Moreover, the variance of the specific component of supply shocks affecting Germany is not statistically significant. This suggests that Germany's supply innovations are not statistically different from the common component. Thus, Germany has a much greater influence on the common component of supply shocks when Greece, Norway, Portugal, Spain and Sweden are excluded from the model. To a lesser extent, the same is true of real demand disturbances. However, in this case, the specific component of real demand shocks to Germany is statistically significant.

France is another interesting case. When non-core European countries are excluded, the

19. The choice of countries to include in Table 5 is admittedly arbitrary to a large extent and is not necessarily based on the degree of shock symmetry observed in Table 4.

20. It is worth mentioning that in all cases, the coefficients associated with the common component have a positive sign (when they are significant) suggesting that common shocks generally have symmetrical effects. Note that the supply shocks affecting Greece, Italy, Norway, Portugal and Sweden are not statistically related to the common European component.

Table 4: Variance decomposition of structural shocks -

European model with 13 countries

Countries	Relative contribution of common component (%)	
	Supply shocks	Real demand shocks
Germany	51	51
France	12	22
United Kingdom	18	13
Italy	5*	5*
Spain	25	12
Netherlands	13	26
Belgium	14	20
Switzerland	44	37
Austria	12	11
Sweden	1*	4*
Norway	0*	0*
Portugal	5*	28
Greece	7*	0*

*Shocks that are not statistically related to the common component (5% significance level).

supply shocks affecting France are no longer statistically related to the common component. This result reflects the relatively strong correlation between supply shocks in France and those in Spain (a country excluded from the second model), as well as between those in Germany and those in Spain.[21] Generally speaking, the symmetry of shocks affecting the other countries does not change significantly when the peripheral countries are excluded. With regard to nominal shocks affecting the European countries, it is interesting to note that it is not possible to generate a statistically significant common component.[22]

To summarize, our main finding is that both supply and real demand shocks affecting the

21. The correlation is 0.30 in the latter case.

22. These results are not reported. Certain cross-correlations are statistically significant (5 per cent significance level) without exhibiting a systematic common relationship.

Table 5: Variance decomposition of structural shocks -

European model with 8 countries

Countries	**Relative contribution of common component (%)**	
	Supply shocks	**Real demand shocks**
Germany	70**	61
France	7*	20
United Kingdom	14	12
Italy	5*	4*
Netherlands	9	26
Belgium	17	18
Switzerland	40	33
Austria	9	13

* Shocks are not statistically related to the common component (5% significance level).

**Specific component's variance is statistically non-significant (5% significance level).

U.S. regions are in general much more symmetrical than those affecting European countries.[23] More specifically, in Europe, only Germany and Switzerland have a degree of symmetry comparable to that found between U.S. regions. In fact, German shocks appear to be the major source of the European common component.[24]

Given these results on shock symmetry, we can identify three separate groups of countries in the formation of an optimum currency area: core, intermediate and peripheral. The countries of the core group would be those whose supply and real demand shocks have a predominant symmetrical component, in this case Germany and Switzerland. The countries included in the intermediate group are those facing shocks that, while being statistically related to the common European component, have a predominant country-specific component. This group would

23. The only major exception is New England in the case of supply shocks.

24. In the case of European countries, Bayoumi and Eichengreen chose Germany as the anchor region for their correlation analysis. Given the predominance of German shocks in the common component, there are more similarities between our respective results regarding shock symmetry than in the case of U.S. regions. One difference is that they generally find a higher degree of symmetry in demand shocks than in supply shocks. This could in part reflect the influence of German monetary policy, since their identified demand shocks include nominal innovations.

include Austria, Belgium, France, the Netherlands, Spain and the United Kingdom. Finally, a peripheral group comprising Italy, Greece, Norway, Portugal and Sweden would include countries whose structural shocks are not statistically related to the symmetrical component of shocks. It is interesting to note that supply shocks are the primary source of output fluctuation in the countries of the peripheral region. The same is true for some countries belonging to the intermediate region (that is, the Netherlands and the United Kingdom). This suggests that the level of shock asymmetry may be related to differences in the countries' respective industrial structures.[25]

Given the high degree of asymmetry of real demand and supply shocks, the European countries may find themselves subject to substantial adjustment costs, particularly in terms of higher variability in output and unemployment, if they completely abandon monetary independence. The extent of these costs will depend on the group to which the country belongs, increasing in magnitude from the core to the periphery, but also on the capacity for alternative adjustment mechanisms – such as price flexibility and intersectoral factor mobility – to compensate for the loss of nominal exchange rate adjustment. The next section attemps to identify the countries with the largest degree of nominal rigidity.

5.3 Speed of adjustment and nominal rigidities

The degree of real shock asymmetry is relevant for the evaluation of the cost of a monetary union only to the extent that nominal rigidities prevent prices from adjusting quickly to bring about the necessary change in the real exchange rate. The purpose of this section is to provide an assessment of the degree of short-term nominal rigidity in each country by measuring the contemporaneous slope of the supply curve at impact and by comparing the speed of adjustment to shocks accross different countries.

5.3.1 Slope of contemporaneous supply curve

One of the advantages of the VAR methodology with long-run restrictions is that it allows for the identification of parameters of simultaneity that can be given a structural interpretation. One of these structural parameters that was uncovered with the method can be interpreted as the slope of the supply curve at impact. For any given country, the higher the degree of price rigidity, the flatter the slope of the short-term supply curve and therefore the greater the effectiveness of monetary policy in affecting output.

25. Such differences are the relative size of the petroleum sector in the case of Norway, and the relatively large agricultural sectors in the case of Greece and Portugal.

Table 6: Slope of short-term supply curve

Country	Slope of supply curve (impact)	Average quarterly inflation rate	
1. Portugal	5.84437	0.04301	(1)*
2. United Kingdom	2.22443	0.02337	(5)
3. Spain	1.68577	0.02918	(3)
4. Greece	0.73819	0.04230	(2)
5. Sweden	0.45550	0.02049	(6)
6. Italy	0.30609	0.02876	(4)
7. Netherlands	0.28639	0.01070	(11)
8. France	0.22837	0.01881	(7)
9. Austria	0.14008	0.01129	(10)
10. U.S.	0.13255	0.01543	(8)
11. Switzerland	0.07594	0.00956	(12)
12. Germany	0.06436	0.00876	(13)
13. Belgium	0.06306	0.01396	(9)

* Rank by average inflation rate, from highest to lowest.

Table 6 shows, for all countries, the slope of the contemporaneous supply curve and the average quarterly rate of inflation. The slope of the supply curve is measured as the ratio of the impact effect of a real demand shock on the price level to the impact effect of the same shock on output.[26] The flattest supply curves are found for Belgium, Germany, Switzerland and the United States. Thus, only three European countries appear to be characterized by a higher degree of nominal rigidity than the United States.

At the other end of the spectrum, we find countries such as Portugal, Spain and the United Kingdom that are characterized by steep short-run supply curves. As shown in Table 6, these

26. The reason the slope of the supply curve was measured using a real demand shock is that, unlike a nominal shock, it generally exerts its maximum effect on output at impact.

countries have also had on average a relatively high inflation rate.[27] Thus, our results indicate that countries with higher average rates of inflation appear to have smaller nominal rigidities and, therefore, demand shocks result in smaller effects on output (steeper short-run supply curves). Moreover, we find that these countries tend to be concentrated in the peripheral region. Consequently, the adjustment costs associated with the high asymmetry of shocks affecting these countries may be mitigated by more rapid price adjustment.

5.3.2 Response to structural shocks

This section provides a brief description of the responses of output, prices and real balances to the three types of structural shocks.[28] By virtue of the identification restrictions, the structural model embodies a vertical long-run supply curve. In order to fully capture the effect of rigidities, it is therefore useful to examine not only the slope of the supply curve at impact but also the speed at which the effect of a temporary shock on output vanishes. In addition, given that the short-term effects and some of the long-term effects of the various structural shocks are not constrained, impulse response functions provide a convenient way to ensure that the shocks that are interpreted as demand and supply innovations have desirable short-run dynamic effects on the endogenous variables of the system. Results that systematically violate our basic economic intuition would cast some doubts on the reliability of the identification method.

The graphs in Appendix 3 present the response of output to the three types of structural shocks. In most cases, positive real demand and nominal shocks have a significant favorable effect on output in the short run.[29] The speed of adjustment of output to these types of shocks varies across countries, with the United States showing the highest degree of persistence and Spain the lowest. In fact, the United States is the only country where the adjustment is not virtually completed after 12 quarters. In addition, in the case of France, Germany and the United States, the maximum effect of a nominal shock on output is felt several quarters after that of a real demand shock as we would expect.

27. This apparent correlation between the degree of rigidity and the level of inflation has been the subject of an empirical examination by Ball, Mankiw and Romer (1988) in the context of an evaluation of the menu-cost theory. Any formal analysis along those lines is beyond the scope of this paper.

28. The reference graphs for some of the European countries as well as for the United States as a whole are included in the appendices at the end of the paper. Since these are for illustration purposes, the impulse response functions of Greece, Norway, Portugal and Sweden are not shown. Except for Greece, the impact of demand shocks on output in these countries is limited even in the short run.

29. Norway represents the only case (not shown in graphs) where a positive real demand shock has a negative effect on output at impact. In the case of a nominal shock, exceptions are found in France, Portugal (not shown in graphs) and Spain. In all three cases, a positive nominal innovation leads to a contemporaneous decline in output. However, this counter-intuitive result is either quickly reversed (France) or happens in a context where the importance of nominal shocks in short-run output variance is negligible (Portugal and Spain).

The graphs shown in Appendix 4 indicate that, as expected, prices are positively correlated to real demand and nominal shocks.[30] In addition, except for Italy and Spain, positive supply shocks have permanent negative effects on prices.[31] As was the case for real output, prices in the United States are slow to adjust compared to those of most European countries, although the difference is not as large as for output. In fact, the graphs show that aggregate prices adjust sluggishly in most countries, including Belgium, Italy and Spain, even though in their case output adjusts quite rapidly.

While the U.S. regions are not included separately in the set of graphs, their impulse response functions generally exhibit a pattern of adjustment that is very similar to that of the United States as a whole. Thus, the speed of adjustment of prices and output is generally slower in the U.S. regions than in European countries. This is consistent with the fact that real exchange rate adjustments between the U.S. regions cannot be facilitated by changes in the nominal exchange rate and, as a result, there is more persistence in the adjustment of output for a given real exchange rate variation.[32] Moreover, in contrast to U.S. regions, several European countries exhibit fairly rapid output adjustment despite very sluggish price adjustment. This difference in the timing of adjustment between output and prices can be seen as an illustration of the role of the nominal exchange rate in facilitating adjustment in the real exchange rate in the presence of sticky prices.

6 Conclusions

In this paper, we address the question of an optimum currency area in Europe by evaluating empirically the degree of asymmetry of supply and real demand shocks between thirteen European countries and, for purposes of comparison, between nine U.S. regions. To do so, we follow a two-step methodology. In the first step, a VAR system of output growth, inflation and money growth is estimated separately for each country (and U.S. region). Then, following the Blanchard-Quah method, we use long-run restrictions to decompose the VAR reduced-form residuals into three structural innovations: supply, real demand and nominal shocks. Overall, we find that supply shocks account for a much larger proportion of output variance in European countries than in U.S. regions.

In the second step, using a state-space methodology, we identify, for supply and real

30. A negative correlation between prices and “real demand” shocks would have suggested the existence of important transitory supply shocks which are not identified in our framework. By definition, under our maintained restrictions, all supply shocks have a permanent effect on the level of output.

31. The surprising result for Italy and Spain occurs only in the long run. Spain is the only country where supply shocks have a positive permanent effect on prices. Nonetheless, supply shocks do have a positive effect on real balances.

32. In their study, Bayoumi and Eichengreen obtain the opposite result that the speed of adjustment is generally faster in the U.S. regions. This could be explained by the fact that we use higher frequency data (quarterly as opposed to annual) or different price measures (consumer price indexes instead of GDP deflators).

demand shocks separately, a common component to all European countries (or U.S. regions) and a country-specific component. The relative importance of the country-specific component can be interpreted as a measure of the degree of asymmetry of real shocks (both demand and supply) in Europe as well as in the United States.

The main conclusion that may be drawn from this analysis is that, relative to U.S. regions, most European countries are facing highly asymmetrical supply and real demand shocks. This is particularly true for the peripheral countries (Greece, Italy, Norway, Portugal and Sweden), which may find the transition period leading to monetary union fairly costly in terms of increased variability in output and unemployment. In fact, the only countries that are closely associated with the common European component of supply and real demand shocks are Germany and Switzerland. Consequently, even countries belonging to the intermediate group (Austria, Belgium, France, the Netherlands, Spain and the United Kingdom) may face significant costs by joining the monetary union.

However, our results indicated that countries characterized by a large degree of shock asymmetry (all peripheral countries) were also the ones showing a high degree of price flexibility. This fact may partially offset the costs due to shock asymmetry. In fact, we found that only three of the thirteen European countries (Belgium, Germany and Switzerland) had flatter short-run supply curves than the United States.

Finally, one should bear in mind that the degree of shock asymmetry, factor mobility and price flexibility are likely to evolve as economic integration leads to profound structural changes in the member countries. However, there is no consensus on the likely effect of higher integration on the degree of shock asymmetry. Some have suggested that it may lead to increased specialization within countries and presumably to a higher degree of shock asymmetry (see Krugman 1991). Others have rejected this view claiming that it has not been supported by historical facts (for example, the higher integration of Spain in the European economy has been accompanied by increased industrial diversification). In any event, our results should be taken as an indication of the costs arising from the increased volatility in output and employment that some countries may face during the transition to EMU, if exchange rates are to be kept fixed, or during the first few years of the post-EMU era.

Appendix 1: Identification of structural shocks

This appendix describes the method for solving the system of equations corresponding to the restrictions of the Blanchard and Quah decomposition method extended to a three-variable system. The notation used is similar to that used in Section 3.1. The following equation represents the vector of the model's dependent variables:

$$\Delta x_t = \begin{bmatrix} \Delta y_t \\ \Delta p_t \\ \Delta m_t \end{bmatrix} \tag{A-1}$$

The matrix of the long-term effects of structural shocks takes the following form:

$$A(1) = \begin{bmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \tag{A-2}$$

Elements A_{12} and A_{13} are set to 0 in accordance with the restriction that nominal shocks and real demand shocks have no long-term effects on output. In addition, the restriction that nominal shocks do not have any permanent effect on real balances means that

$$A_{23} = A_{33} \tag{A-3}$$

In order to transform the matrix of the long-term effects of structural shocks into triangular form, equation (A-2) is premultiplied by matrix *B*:

$$B = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix}$$

The result is the lower triangular matrix *A2*:

$$A2 = BA(1) \tag{A-4}$$

From equations (9) and (10) of section 2, the following relation may be obtained:

$$C(1)\Sigma C(1)' = A(1)A(1)' \tag{A-5}$$

Given equation (A-4), the following relation must hold:

$$BC(1)\Sigma C(1)'B' = A2A2' \tag{A-6}$$

Given that *A*2 is a triangular matrix, to solve for the elements of *A*2, the Choleski decomposition is applied to the left-hand side of equation (A-6) that contains known elements. Next, *A*2 is pre-multiplied by the inverse of *B* to obtain the matrix of long-term effects A(1):

$$A(1) = B^{-1}A2 \tag{A-7}$$

Next, A_0 is solved:

$$A_0 = C(1)^{-1}A(1) \tag{A-8}$$

Finally, the structural shocks are identified using the following relation:

$$\varepsilon_t = A_0^{-1}e_t \tag{A-9}$$

Appendix 2: Unit-root and cointegration tests

The set of long-run restrictions used to identify the structural disturbances have implications regarding the assumed process followed by some of the variables. Some of these implications can be tested. First, unlike demand shocks, supply shocks can have permanent effects on output. It follows that the output level should be characterized as the sum of a (stochastic) permanent component and a transitory component and should be a first-order integrated process. Second, both supply and real demand shocks are assumed to have a permanent effect on real balances. This implies that money and prices should not be co-integrated. Finally, given that both supply and real demand shocks may have permanent effects on velocity, one should test whether velocity is nonstationary.

To verify these hypotheses, unit-root tests were applied to the level (in logarithm) and change (first difference) of the three variables for each country (or region). Table A2-1 (p. 28) on the following page gives the Phillips-Perron (PP) and augmented Dicky-Fuller (ADF) statistics. The results indicate that, with only two exceptions, the levels of output, money and prices are I(1). In the case of the two exceptions, only the PP test rejects the unit root. As shown in Table A2-2 (p. 29), the results of the tests on inflation are ambiguous, except for France, where nonstationarity cannot be rejected. However, in the case of France, the results of tests incorporating a deterministic trend indicate a rejection of a unit root.[1] The tests of the M1 growth rate generally reject the hypothesis of nonstationarity. Given these results, the dependent variables are introduced in first-difference form in the VAR system.

The tests for cointegration between money and prices use the Engle and Granger method; the results are shown in Table A2-3 (p. 30). Since the hypothesis of non-cointegration among money and prices cannot be rejected, the results are consistent with the hypothesis that real balances are nonstationary.[2] Lastly, the hypothesis of a unit root in velocity was tested. The results shown in Table A3 indicate that, in all cases, the hypothesis of a unit root in velocity cannot be rejected.

For comparison purposes, the tests described above were also applied to the U.S. regions.[3] The results were basically the same as for the European countries. Overall, the results indicate that, for each of the regions, the hypothesis of a unit root in the level of variables cannot be rejected. The hypotheses that neither real balances nor velocity are stationary cannot be rejected empirically for any of the U.S. regions on the basis of the tests described here. Lastly, as for the

1. In light of this result, a trend component was added to the VAR system for France. It may be recalled that France was the only case where a monetary aggregate other than M1 was used (that is, M3).

2. With the exception of Sweden and, partially, Greece.

3. The complete results are not reported here, but are available in Lalonde and St-Amant (1993).

European countries, the evidence on stationarity of inflation is ambiguous.

Table A2-1: Unit-root tests

Countries	Price		Money		Output	
	ADF[a]	PP[b]	ADF	PP	ADF	PP
Austria	-1.15 (1)	-1.90	1.27 (0)	1.18	0.35 (1)	0.47
Belgium	-1.74 (3)	-0.57	-0.42 (4)	-0.02	-0.54 (2)	-0.12
Spain	0.29 (4)	0.52	1.79 (4)	2.85	-0.25 (4)	-41.40[c]
France	-1.13 (1)	-0.59	1.36 (1)	5.05	-0.69 (1)	-0.73
Greece	2.84 (4)	3.2	6.61 (4)	2.85	-2.08 (0)	-2.80
Germany	-0.18 (3)	-0.70	2.54 (0)	2.47	0.69 (0)	0.75
Italy	-0.15 (3)	0.47	2.21 (4)	1.32	-0.99 (1)	-3.57
Netherlands	-0.76 (4)	-1.32	0.98 (0)	0.56	-0.59 (0)	-0.02
Norway	0.13 (2)	0.37	0.72 (5)	1.87	-0.09 (1)	0.14
Portugal	3.34 (1)	1.68	0.58 (5)	2.19	0.29 (0)	0.24
Sweden	1.18 (4)	0.99	1.43 (4)	0.90	-1.72 (3)	-5.74
Switzerland	1.05 (4)	0.10	-0.96 (1)	-1.33	-0.09 (4)	-22.90
United Kingdom	-0.07 (2)	0.26	-1.04 (3)	-0.53	-0.94 (0)	-2.33
United States	-0.72 (3)	-0.07	0.86 (5)	0.87	-0.58 (1)	-0.48

a. The number of lags used for the ADF test given in parentheses. The critical value of the ADF test is 2.89.

b. The number of lags for the PP test is calculated as INT(T) = 8. The critical value of the PP test is 13.70.

c. Bold figures indicate cases where the null hypothesis of a unit root is rejected (5 per cent significance level).

Table A2-2: Unit-root test on velocity and cointegration test on money and price

Countries	Velocity		Cointegration	
	ADF[a]	PP[b]	ADF[c]	PP
Austria	-1.63 (1)	-4.52	-0.96 (0)	-4.15
Belgium	-1.0 (4)	-5.15	-1.79 (4)	-7.88
Spain	-1.08 (4)	-3.15	-2.22 (4)	-2.02
France	-0.75 (0)	-0.80	-2.55 (5)	-5.87
Greece	-0.95 (4)	-4.08	-2.38 (5)	-19.71[d]
Germany	-1.26 (3)	0.06	-0.93 (1)	-3.98
Italy	-2.71 (4)	-13.20	-1.72 (4)	-2.43
Netherl.	-1.19 (0)	-3.45	-1.69 (1)	-4.75
Norway	0.09 (3)	-1.39	-1.49 (5)	-2.96
Portugal	-2.01 (4)	-2.55	-2.45 (5)	-5.42
Sweden	-1.87 (4)	-6.56	**-3.98** (4)	-16.64
Switzerland	-1.53 (4)	-7.17	-2.62 (3)	-9.50
United Kingdom	-1.05 (0)	-0.83	-2.26 (3)	-9.20
United States	-2.06 (1)	-4.81	-2.04 (5)	-5.29

a. The number of lags used for the ADF test is given in parentheses. The critical value of the ADF test is -2.89.

b. The number of lags for the PP test is calculated as INT(T) = 8. The critical value of the PP test is -13.70.

c. For the bivariate (cointegration) case, the critical value of the test is -3.42.

d. Bold figures indicate cases where the null hypothesis of a unit root is rejected (5 per cent significance level).

Table A2-3: Unit-root tests

Countries	Inflation		Money growth rate	
	ADF[a]	PP[b]	ADF	PP
Austria	-1.89 (3)	**-65.43**[c]	**-8.31 (0)**	**-76.06**
Belgium	-2.71 (4)	**-14.24**	**-6.87 (2)**	**-122.96**
Spain	-0.84 (3)	**-97.47**	**-2.92 (4)**	**-76.30**
France	-1.54 (5)	**-30.38**	**-5.06 (0)**	**-35.30**
Greece	**-3.76 (4)**	**-154.91**	**-6.66 (3)**	**-86.55**
Germany	-2.35 (2)	**-20.19**	**-7.91 (0)**	**-65.78**
Italy	-1.87 (2)	**-20.62**	-2.87 (4)	**-71.30**
Netherlands	-1.70 (3)	**-25.61**	**-7.05 (0)**	**-54.18**
Norway	-2.66 (1)	**-42.07**	**-3.65 (3)**	**-72.27**
Portugal	-1.93 (3)	**-82.44**	**-5.72 (0)**	**-54.79**
Sweden	**-2.93 (2)**	**-73.77**	**-2.93 (4)**	**-55.22**
Switzerland	**-3.94 (2)**	**-44.48**	**-4.54 (4)**	**-56.94**
United Kingdom	-2.47 (1)	**-40.63**	**-6.62 (0)**	**-66.16**
United States	-1.48 (2)	**-17.61**	-2.45 (4)	**-43.01**

a. The number of lags used for the ADF test is given in parentheses. The critical value of the ADF test is 2.89.

b. The number of lags for the PP test is calculated as INT(T) = 8. The critical value of the PP test is -13.70.

c. Bold figures indicate cases where the null hypothesis of a unit root is rejected (5 per cent significance level).

Appendix 3: Industrial production index impulse response

Figure A3-1: Industrial production index impulse response (France, Germany, United Kingdom, United States)

- one-standard deviation supply shock ———
- one-standard deviation nominal shock **..........**
- one-standard deviation real demand shock -------

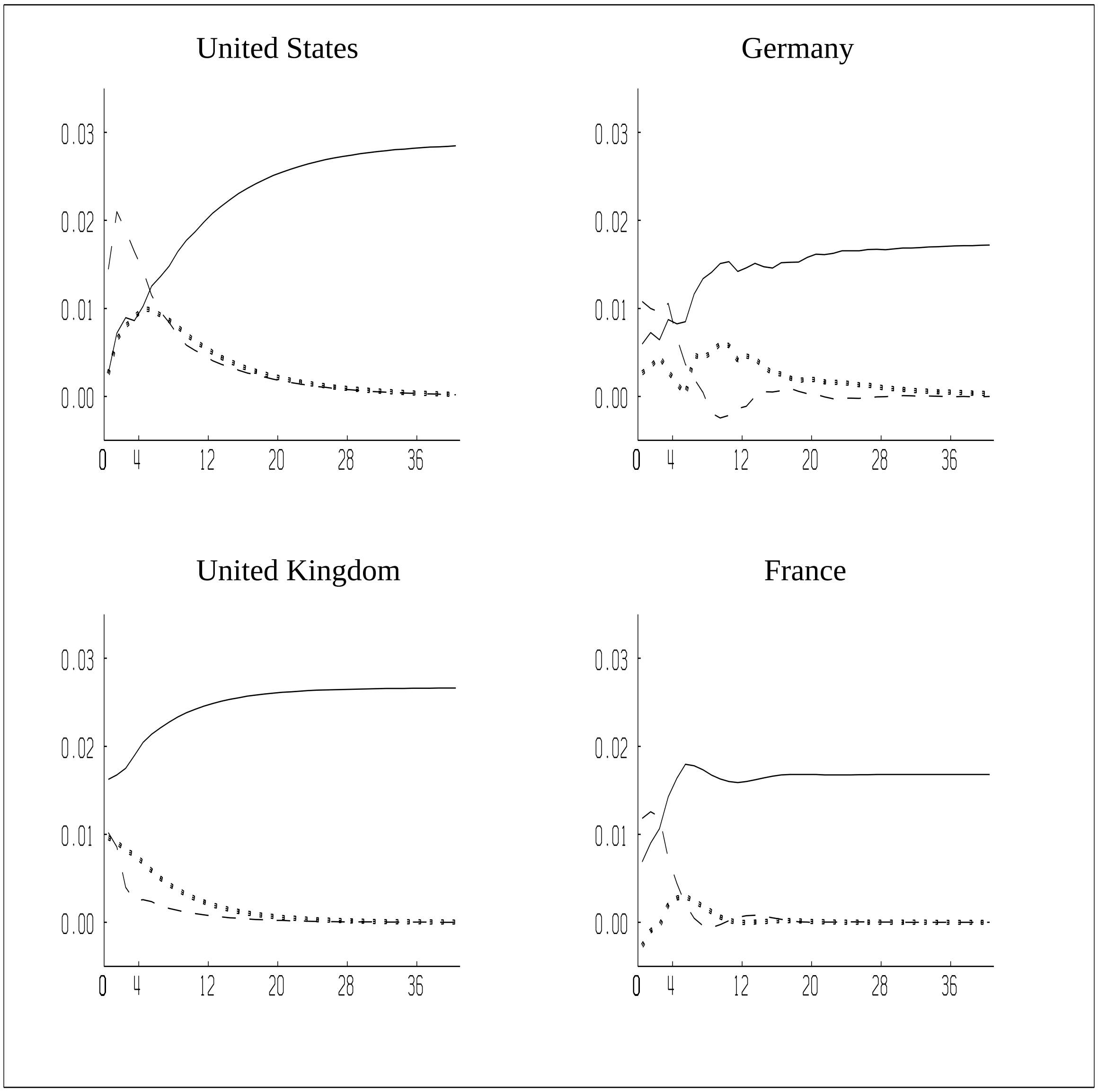


Figure A3-2: Industrial production index impulse response (Austria, Belgium, Netherlands, Switzerland)

- one-standard deviation supply shock ———
- one-standard deviation nominal shock **..........**
- one-standard deviation real demand shock -------

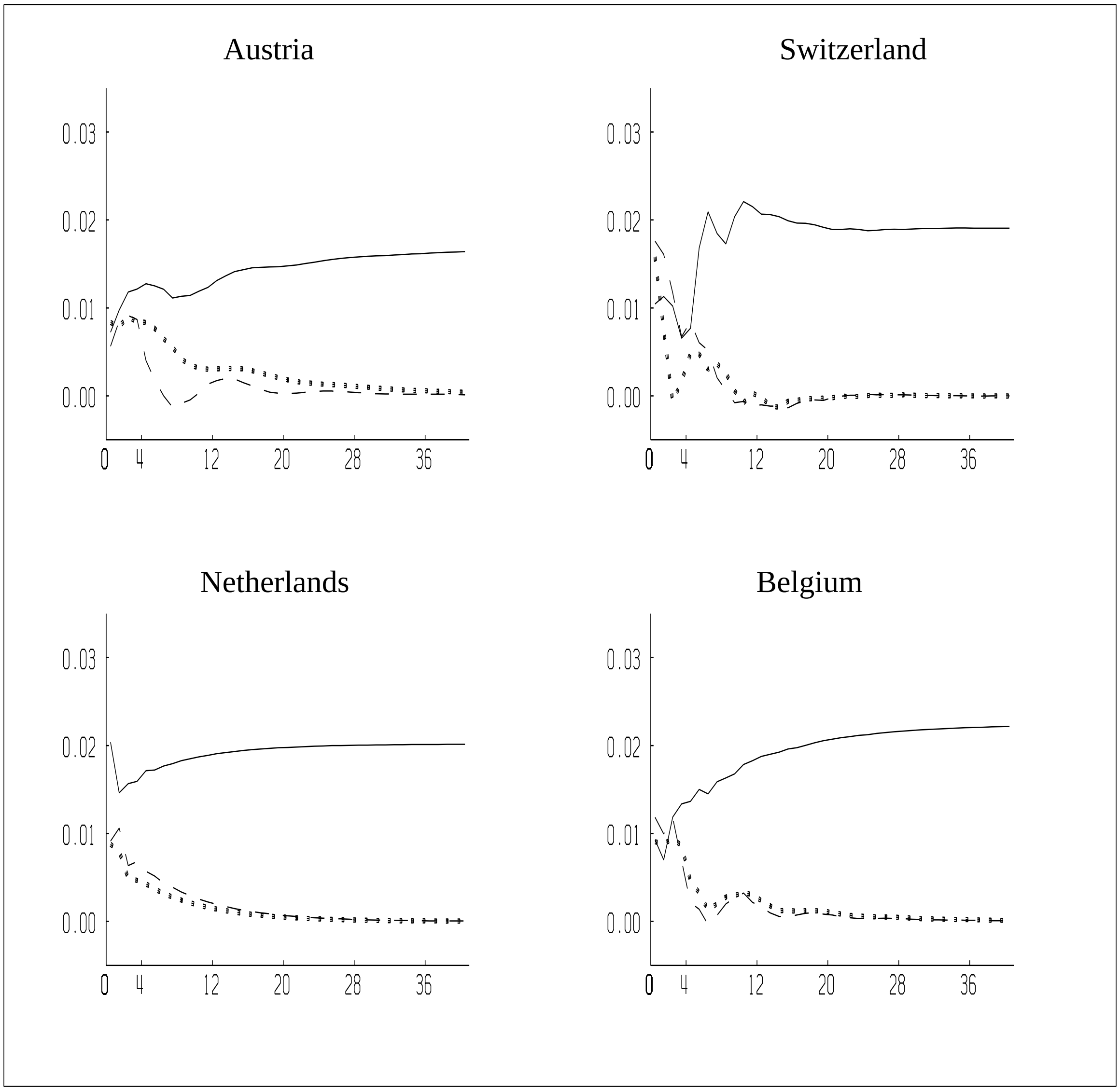
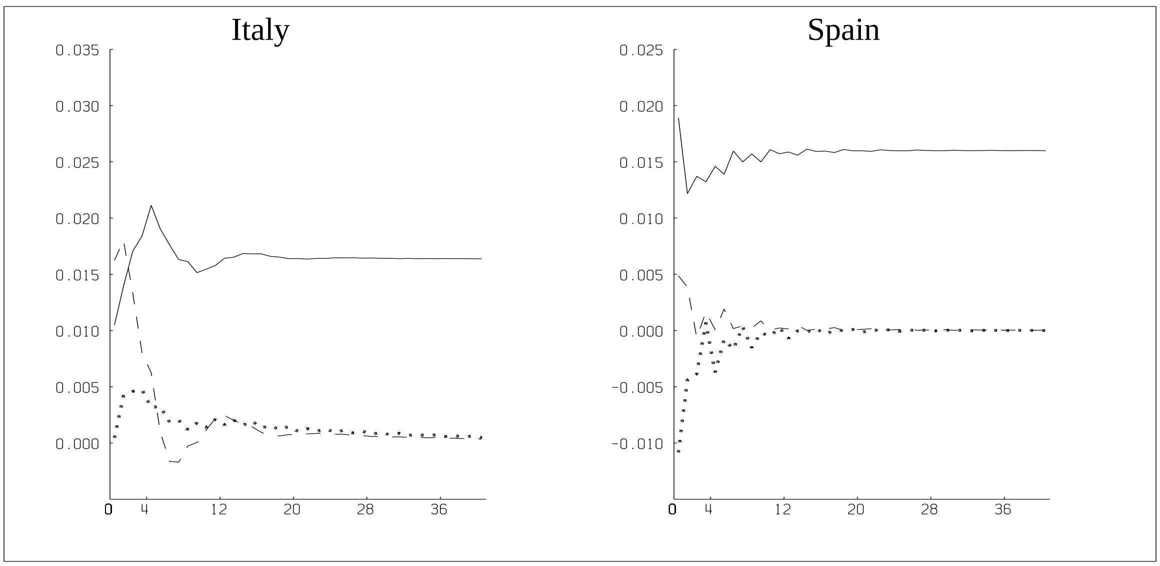


Figure A3-3: Industrial production index impulse response (Italy and Spain)

- one-standard deviation supply shock ———
- one-standard deviation nominal shock **..........**
- one-standard deviation real demand shock -------



Appendix 4: Price (CPI) impulse response

Figure A4-1: Price (CPI) impulse response
(France, Germany, United Kingdon, United States)

- one-standard deviation supply shock ———
- one-standard deviation nominal shock **..........**
- one-standard deviation real demand shock -------

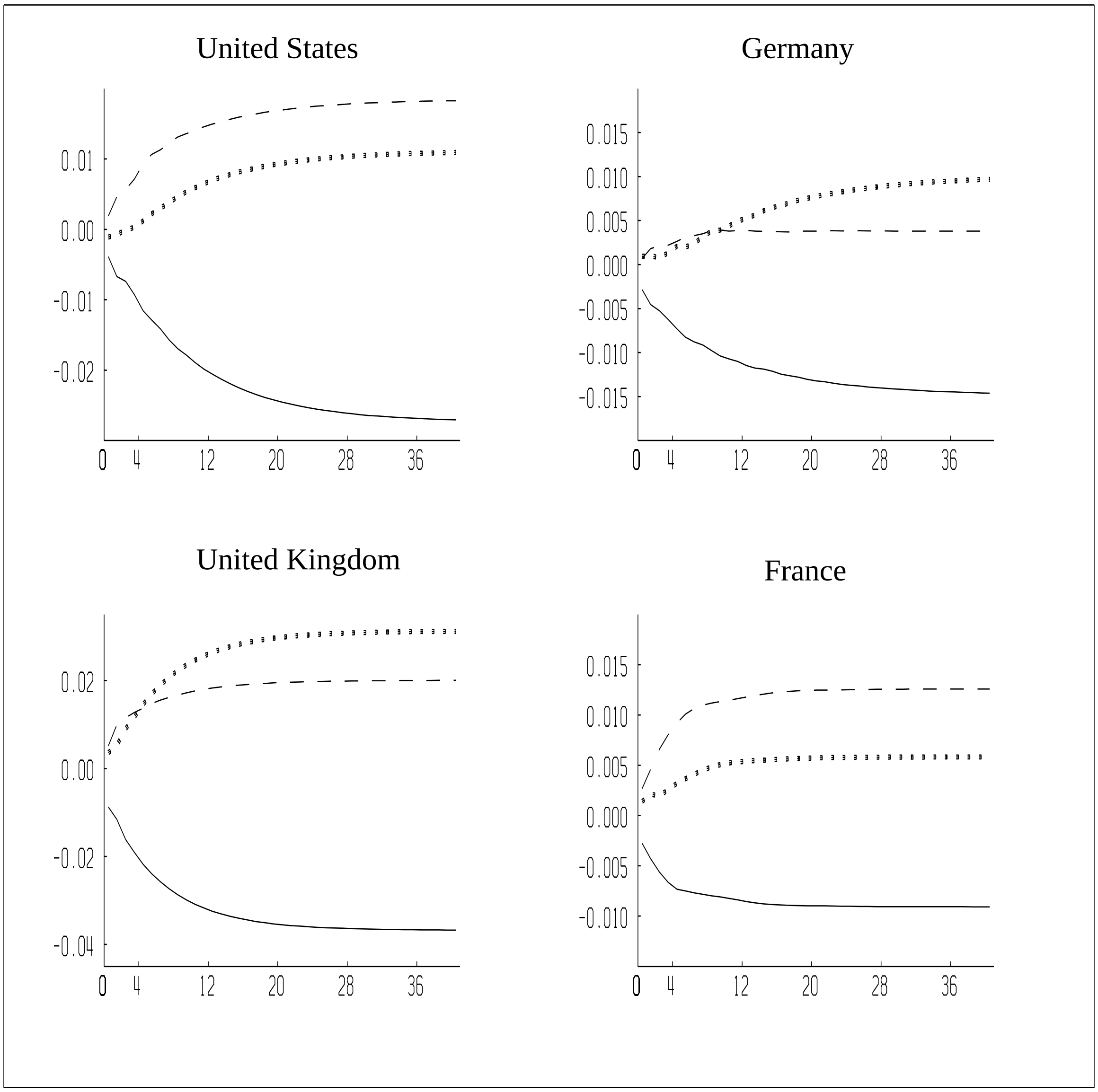


Figure A4-2: Price (CPI) impulse response (Austria, Belgium, Netherlands, Switzerland)

- one-standard deviation supply shock ———
- one-standard deviation nominal shock **..........**
- one-standard deviation real demand shock -------

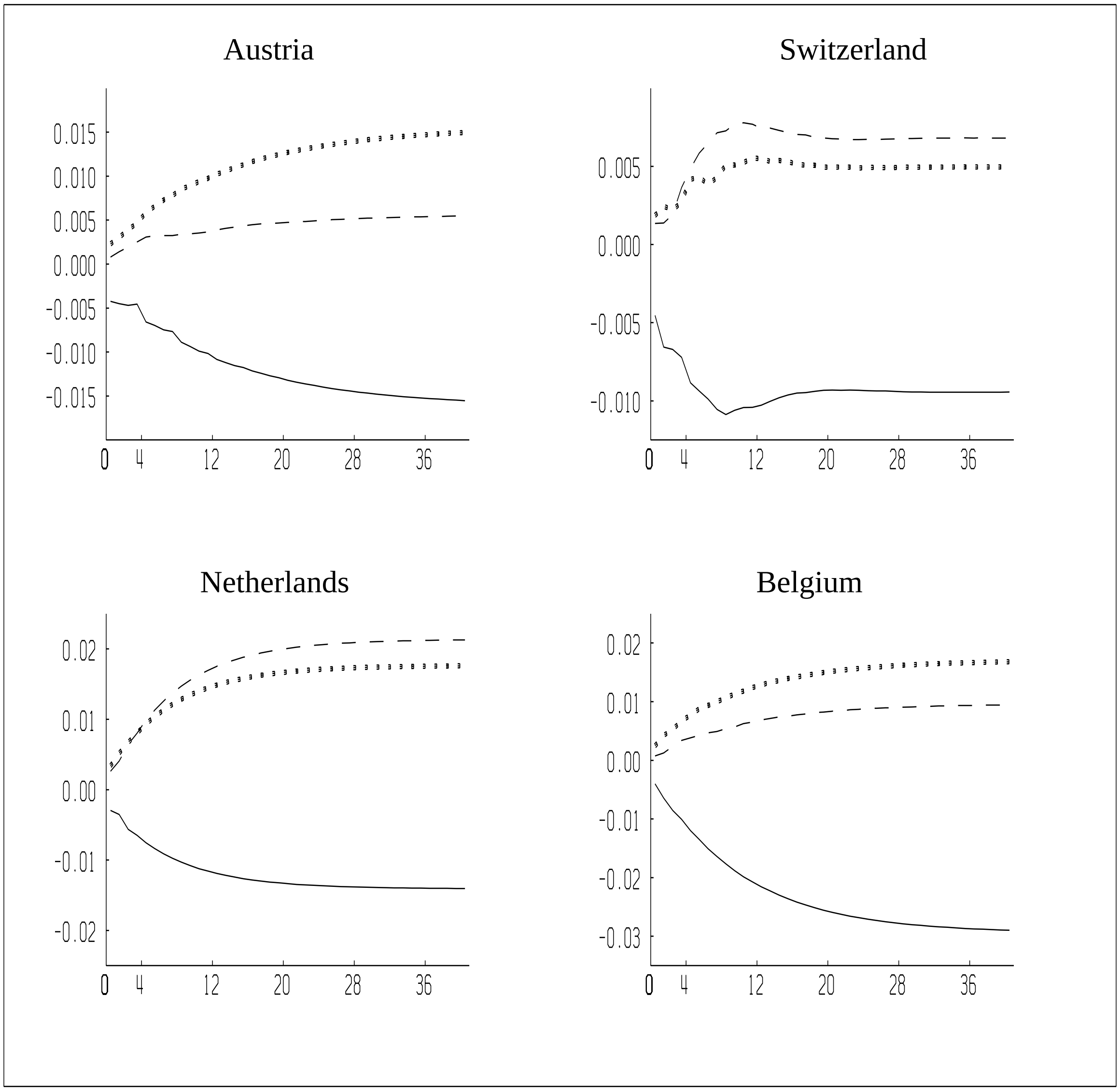
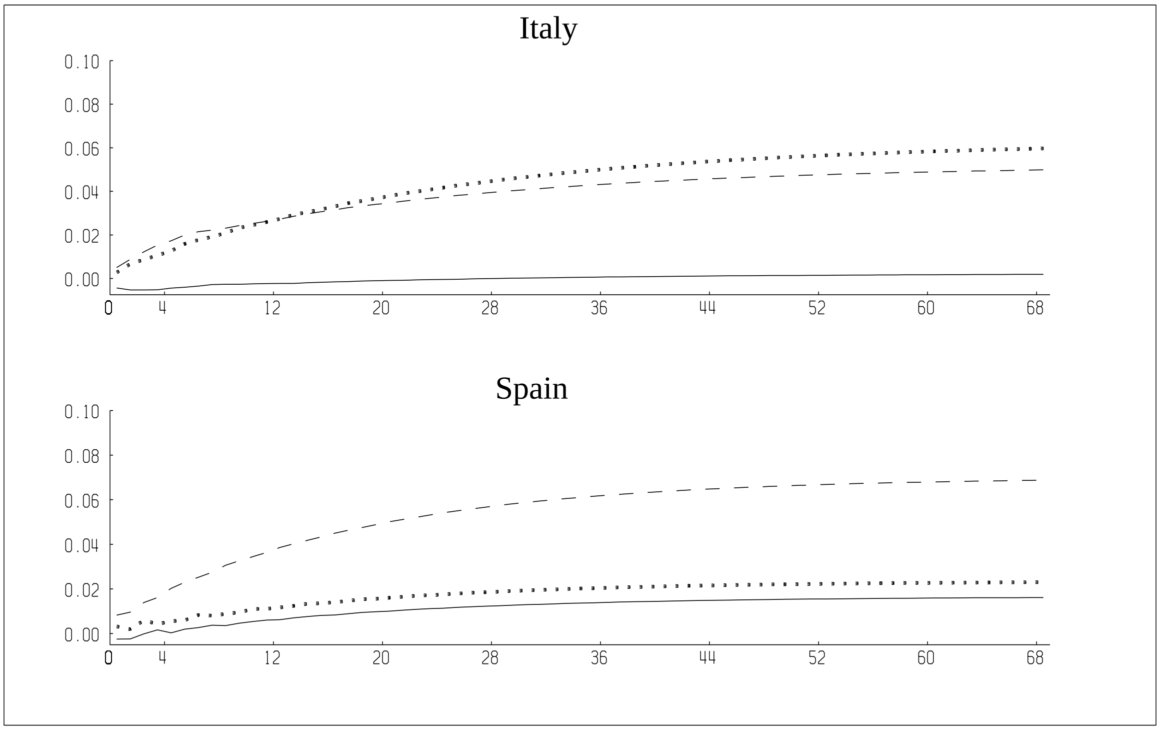


Figure A4-3: Price (CPI) impulse response (Italy and Spain)

- one-standard deviation supply shock ———
- one-standard deviation nominal shock **..........**
- one-standard deviation real demand shock -------



Bibliography

Amano, R. and S. van Norden. 1992. “Unit Root Tests and the Burden of Proof.” Working Paper 92-7. Bank of Canada, Ottawa.

Ball, N., G. Mankiw and D. Romer. 1988. “The New Keynesian Economics and the Output-Inflation Trade-off.” *Brookings Papers on Economic Activity* 1:1-82.

Bayoumi, T. and B. Eichengreen. 1992. *Shocking Aspects of Monetary Unification*. Working Paper No. 3949. National Bureau of Economic Research, Cambridge, MA.

Blanchard, O. and D. Quah. 1989. “The Dynamic Effect of Aggregate Demand and Supply Disturbances.” *American Economic Review* 79:655-673.

Blanchard, O. and D. Quah. 1993. “The Dynamic Effect of Aggregate Demand and Supply Disturbances: Reply.” *American Economic Review* 83:653-58.

Cohen, D. and C. Wyplosz. 1989. “The European Monetary Union: An Agnostic Evaluation.” Discussion Paper No. 306. Center for Economic Policy Research.

Cooley, T. F. and S. F. Leroy. 1985. “Atheoretical Macroeconometrics: A Critique.” *Journal of Monetary Economics* (November): 283-308.

DeSerres, A. and R. C. Lalonde. 1993. “Sources de fluctuation des taux de change en Europe: implications concernant l'union monétaire.” Technical Report No. 66. Bank of Canada, Ottawa.

Dickey, D. A. and W. A. Fuller. 1979. “Distribution of the Estimator for Autoregressive Time Series with a Unit Root.” *Journal of the American Statistical Association* 74:427-36.

Eichengreen, B. 1993. “European Monetary Unification.” Journal of Economic Literature 31:1321-57.

Engle, R. F. and C. W. J. Granger. 1987. “Cointegration and Error Correction: Representation, Estimation and Testing.” *Econometrica* 55:251-76.

Engle, R. F. and M. W. Watson. 1983. “Alternative Algorithms for Estimation of Dynamic MIMIC, Factor and Time Varying Coefficient Regression Models.” *Journal of Econometrics* 23:385-400.

Fenton, P. and J. Murray. 1993. “Optimum Currency Areas: A Cautionary Tale.” In *The Exchange Rate and the Economy,* Proceedings of a Conference Held at the Bank of Canada 22-23 June 1992, 485-531 Ottawa: Bank of Canada.

Harvey, A. C. 1981. *The Econometric Analysis of Time Series*. Oxford, England: Philip Allen.

Judge, G. G., R. Carter Hill, W. E. Griffiths, H. Lutkepohl and T.-C. Lee. 1982. *Introduction to the Theory and Practice of Econometrics*. New York: John Wiley & Sons.

Kenen, P. 1969. “The Theory of Optimum Currency Areas: an Eclectic View.” In *Monetary Problems of the International Economy.* Conference on International Monetary Problems, edited by R. Mundell and A. K. Swoboda, 41-60. Chicago: University of Chicago Press.

Krugman, P. 1991. *Economic Geography and International Trade*. Cambridge, MA: MIT Press.

Kwiatkowski, D., P. C. B. Phillips and P. Schmidt. 1991. “Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure Are We That Economic Series Have a Unit Root?” Discussion Paper No. 797. Cowles Foundation of Research in Economics at Yale University, New Haven, CT.

Lalonde, R. C. and P. St-Amant. 1993. “Zones monétaires optimales: cas du Mexique et des États-Unis.” Working Paper 93-12. Bank of Canada, Ottawa.

Lippi, M. and L. Reichlin. 1993. “The Dynamic Effect of Aggregate Demand and Supply Disturbances: Comment.” *American Economic Review* 83:644-52.

Masson, P. R. et M. P. Taylor. 1992. “Common Currency Areas and Currency Unions: An Analysis of the Issues.” Discussion Paper 617, Centre for Economic Policy Research.

McKinnon, R. I. 1963. “Optimum Currency Areas.” *American Economic Review* 53: 717-24.

McLeod, D. and J. H. Welch. 1991. Free Trade and the Peso. Research Paper No. 9115, Federal Reserve Bank of Dallas.

Mundell, R. 1961. “A Theory of Optimum Currency Areas.” American Economic Review 51:657-665.

Phillips, P. C. B. and P. Perron. 1988. “Testing for a Unit Root in Time Series Regressions.” *Biometrika* 75:335-346.

Raynauld, J., J. G. Simonato and C. Sigouin. 1992. “A Program for the Estimation of General State-Space Models Using the Scoring and EM Algorithms.” Mimeo. Université de Montréal.

Schmidt, P. and P. C. B. Phillips. 1992. “Testing for a Unit Root in the Presence of Deterministic Trends.” *Oxford Bulletin of Economics and Statistics* 54:257-288.

Shin, Y. 1992. “A Residual-Based Test of the Null of Cointegration Against the Alternative of No Cointegration.” Manuscript. Department of Economics, Michigan State University, East Lansing.

Weber, A. 1990. “EMU and Asymmetries and Adjustment Problems in the EMS: Some Empirical Evidence.” Discussion Paper No. 448. Centre for Economic Policy Research.

Bank of Canada Working Papers

1994

94-1 Optimum Currency Areas and Shock Asymmetry: A Comparison of Europe and the United States — N. Chamie, A. DeSerres and R. Lalonde

1993

93-1 The Implications of Nonstationarity for the Stock-Adjustment Model — R. A. Amano and T. S. Wirjanto

93-2 Speculative Behaviour, Regime Switching and Stock Market Fundamentals — S. van Norden and H. Schaller

93-3 Terms of Trade and Real Exchange Rates: The Canadian Evidence — R. A. Amano and S. van Norden

93-4 State Space and ARMA Models: An Overview of the Equivalence — P. D. Gilbert

93-5 Regime Switching as a Test for Exchange Rate Bubbles — S. van Norden

93-6 Problems in Identifying Non-linear Phillips Curves: Some Further Consequences of Mismeasuring Potential Output — D. Laxton, D. Rose and R. Tetlow

93-7 Is the Canadian Phillips Curve Non-linear? — D. Laxton, D. Rose and R. Tetlow

93-8 The Demand for M2+, Canada Savings Bonds and Treasury Bills — K. McPhail

93-9 Stockout Avoidance Inventory Behaviour with Differentiated Durable Products — P. H. Thurlow

93-10 The Dynamic Demand for Money in Germany, Japan and the United Kingdom — R. A. Amano and T. S. Wirjanto

93-11 Modèles indicateurs du PIB réel pour quatre pays d'Europe et le Japon — P. Gruhn and P. St-Amant

93-12 Zones monétaires optimales : cas du Mexique et des États-Unis — R. Lalonde and P. St-Amant

93-13 Is Productivity Exogenous over the Cycle?: Some Canadian Evidence on the Solow Residual — B. Cozier and R. Gupta

93-14 Certainty of Settlement and Loss Allocation with a Minimum of Collateral — W. Engert

93-15 Oil Prices and the Rise and Fall of the U.S. Real Exchange Rate — R. A. Amano and S. van Norden

1992

92-4 Les taux à terme administrés des banques — J.-P. Caron

92-5 An Introduction to Multilateral Foreign Exchange Netting — W. Engert

92-6 Inflation and Macroeconomic Performance: Some Cross-Country Evidence — B. Cozier and J. Selody

92-7 Unit Root Tests and the Burden of Proof — R. A. Amano and S. van Norden

Single copies of Bank of Canada papers may be obtained from

Publications Distribution
Bank of Canada
234 Wellington Street
Ottawa, Ontario K1A 0G9